(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 713 286 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
04.03.1998 Bulletin 1998/10

(51) Int Cl.^{6}: **H02P 1/16**

(21) Application number: **95203615.0**

(22) Date of filing: **07.06.1994**

(54) Method of starting an electric machine

Verfahren zum Anlaufen einer elektrischen Maschine

Méthode de démarrage d'une machine électrique

(84) Designated Contracting States:
DE ES FR GB IT NL SE

(30) Priority: **07.06.1993 GB 9311694**

(43) Date of publication of application:
22.05.1996 Bulletin 1996/21

(60) Divisional application: **97201692.7 / 0 802 620**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
94304056.8 / 0 630 097

(73) Proprietor: **SWITCHED RELUCTANCE DRIVES LIMITED**
Harrogate, North Yorkshire HG3 1PR (GB)

(72) Inventor: **Brown, Geoffrey T.**
Hemingbrough, North Yorkshire, Y08 7RE (GB)

(74) Representative: **Hale, Peter et al**
Kilburn & Strode
30 John Street
London WC1N 2DD (GB)

(56) References cited:
EP-A- 0 193 708
WO-A-90/00325
US-A- 5 111 095
EP-A- 0 378 351
DE-A- 4 305 321

Remarks:
Divisional application 97201692.7 filed on 04/06/97.

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Printed by Jouve, 75001 PARIS (FR)

Description

This invention relates to a method of starting electric machines. The invention is particularly, though not exclusively, applicable to switched reluctance (SR) machines.

The switched reluctance drive is a variable-speed drive system comprising an electric motor supplied from a power-electronic converter under the control of low-power control electronics. The motor has salient poles on both the stator and the rotor, typically with an excitation coil around each stator pole. These stator coils are grouped to form one or more phase windings. The electrical currents in the windings are typically switched on and off by power-electronic switches.

The timing of the switching of the currents in the windings is controlled in relation to the relative angular position of the stator and rotor poles. This relative position may be detected by a rotor position transducer which consists of a rotating member and stationary sensors which supply signals to the control electronics. In single and two-phase systems only a single sensor is required, but motors with more than two phases generally use more than one sensor according to the prior art.

Figure 1 shows a schematic diagram of a typical 3-phase SR motor, which has six stator poles and four rotor poles. The poles carrying coils A and A' have opposite magnetic polarisation. Phases B and C are formed similarly.

A rotor position transducer (RPT) is used to ensure that the currents of the phase windings are switched on and off at the appropriate angles of rotation. Figure 2a illustrates a typical system consisting of a rotating slotted disc and three optical sensors which are switched by the rotation of the disc.

Figure 2b shows the idealised variation of the inductances of the phase windings as functions of angle of rotation θ. Positive torque is defined as that which acts in the direction to move the rotor in the direction of positively increasing θ. Such torque is produced by any phase when the winding of that phase carries current and the angle of rotation is such that the inductance is increasing with increasing θ. Negative torque is produced when a phase carries current during that part of its inductance cycle where the inductance is decreasing with increasing θ (or increasing with decreasing θ).

It will be apparent therefore that for normal positive torque operation in the direction of increasing θ (the forward direction) each phase is energised in turn when its inductance is increasing. Figure 2b also shows the three output signals of the sensors according to prior art. In general the RPT consists of three sensors, which may for example, be optical, magnetic or inductive, which co-operate with a rotating member, for example a disc with cut out slits, to produce signals such as those shown in Figure 2b as RPT_A, RPT_B and RPT_C. Thus the signal RPT_A changes from zero to a positive value at the centre of the minimum inductance region of phase A and returns to zero at the maximum inductance position of phase A. The signals RPT_B and RPT_C behave in the same manner for phases B and C respectively. It will be clear that whether the rotor is starting from rest in either the forward or backward direction or running in either direction, the RPT signals enable the control electronics to excite the appropriate phase winding over the appropriate angle of rotation to produce torque in the desired direction.

The torque developed by the motor may be controlled at low speeds by adjusting the magnitude of the current in the phase windings over the fixed angle defined by the respective positive or negative RPT signals depending on the desired direction of torque. At high speed the torque is normally controlled by adjusting the angle over which a phase winding is switched onto the power supply and the angle with respect to the inductance cycle at which the switching on takes place, i.e. by timing the switching on and off of the phase energisation with reference to the RPT signals. It will be clear from Figure 2b that the combined RPT signals can be used to determine the rotor position to one sixth of a phase period thus giving a 15 degree resolution. For more refined control of switching angles, each of these six regions can be interpolated, for example, by using a high frequency pulse train which is phase locked to the low frequency RPT signals as described in GB 1597790 (Stephenson).

US 4990843 (Moren) describes a method by which the three detectors of Figure 2a may be replaced by a single detector. The rotating disc incorporates six or twelve slots, giving a sensor signal which has respectively a rising or falling edge every 30 degrees of rotation, or a falling edge every 30 degrees of rotation, which may be used to switch the phase winding currents of the motor. However, the method suffers from the serious disadvantage that correct tracking of the relationship between edges and phases may be lost due to electrical noise, for example, in the sensor signal.

EP-A-0193708 discloses a method of starting a two-phase reluctance machine which includes energising both phases simultaneously, when the rotor is parked in a zero torque position, so that the resulting flux asymmetry shifts the rotor into a position in which conventional excitation can take over.

EP-A-0378351 discloses a relative position transducer for determining the angular position of a first member relative to a second member. A read head is influenced by a set of evenly and unevenly spaced features. The passage of the features provides position information that is decoded by a microcomputer.

It is an object of the present invention to provide start-up procedures for electric machines using position information from a rotor encoder.

The present invention provides a method of starting an electric machine as defined in the accompanying independent claim. Preferred features of the invention are recited in the dependent claims.

The encoder can be used to determine the orientation of the rotor relative to the stator from the intermediate position of the rotor and the output from the sensor when the rotor is in that intermediate position.

Preferably, the method includes switching one of the phases of the machine thereafter to cause rotation of the rotor between angular positions at which the said switched phase can further rotate the rotor.

It may be necessary to develop a suitable motor speed before polyphase control of the motor can be initiated. In this case this 'single phase' start-up running of the motor according to the invention may be effected for more than one cycle of the rotor until the rotor speed allows the rotor position to be accurately determined at any position.

The present invention can be put into practice in various ways some of which will now be described by way of example with reference to the accompanying drawings in which:

Figure 3 is a timing diagram for the rotor position sensor output;
Figure 4 is a timing diagram for starting a rotor according to the invention;
Figure 5 is a timing diagram of a modification of the starting procedure;
Figure 6 is a circuit diagram of a motor control circuit for a switched reluctance motor; and
Figure 7 illustrates an encoder.

Referring to Figures 6 and 7, a control system for a switched reluctance motor comprises a rectifying and smoothing circuit 10 which receives an a.c. mains input. The smoothed rectified d.c. output from the circuit 10 is applied to a power convertor 12 which provides a three-phase switched supply for a 6 stator pole/4 rotor pole, 3-phase switched reluctance motor 14 as shown in Figure 1. The power convertor comprises a set of phase power switches such as electronic power transistor switches which gate the supply of d.c. current to the 3 motor phases.

A rotor position sensor 16 is arranged at the periphery of a shaft encoder 18 mounted to rotate with the rotor shaft 19 (see Figure 7). The sensor 16 may be a Hall-effect sensor or an optical sensor. The encoder is formed with a sequence of features of marks and spaces 20,22. In the case of a Hall-effect sensor these may be constituted by a sequence of lands and recesses which are respectively closer to and more distant from the sensing face of the sensor 16 or a sequence of coded magnetised regions in the path of the sensor. In the case of an optical sensor,there is also a light source and the marks and spaces may be respectively constituted by light absorbing and light reflecting parts or light passing slots and light blocking castellations. Of course, other forms of sensor, such as a capacitance sensor, could be used to equal effect.

The signals from the sensor are transmitted to a microprocessor-based controller 24. Based on the information received from the sensor, the feedback from the power switches in the form of phase current sensing signals and the drive commands from the user, the controller 24 issues signals to the power switches. It will be appreciated by the skilled person that other forms of controller are contemplated, such as a hardwired logic controller.

The single detector method overcomes the problem of loss of tracking in the prior art. The falling edges (i.e. the trailing edges producing a low output from the sensor) in this system are used to give more information on actual position and direction of rotation. For example they may be placed at either ¼ or ¾ of the distance between adjacent rising edges thus producing either a short or a long pulse respectively as the rotor rotates. These short and long pulses may be spaced around the disc in a repeating pattern consisting of six pulses corresponding to one phase period. The phase period repeats every 90° of the encoder. The pattern chosen may be 'LLSSLS' where L = long pulse and S = short pulse. To give binary numbers for the decoding logic, a long pulse may be decoded as a '1' and a short pulse decoded as a '0'. This gives an output code sequence of '110010' which continually repeats as the disc is rotated past the sensor. The sequence of circumferential marks and spaces in the encoder of Figure 7 is a reproduction of the sequence 110010 according to this convention. Although a 6-bit code is used, 3-bits is adequate to create a code to identify the rotor position with sufficient resolution within the phase period. The additional redundancy in the 6-bit sequence allows more reliable error checking.

When the rotor is rotating, the code may be read in with the last six bits being stored. The code may be updated when each rising edge is received. The state of the received code then gives the position of the rotor to within one sixth of a phase period, as for the original three-detector system. Figure 3 shows the example sensor code in relation to the maximum and minimum inductance positions for the three phases. It will be clear that the code could be positioned with any 15 degree orientation in relation to the phase inductances.

While the code sequence is arranged to repeat on the encoder every phase inductance cycle in this embodiment, i.e. once per rotor pole, the position information could be derived from a longer code spanning up to the complete circumference of the encoder disc. However, the shorter sequence coinciding with the phase inductance cycle provides all the information for position and timing necessary while keeping the sequence period as short as possible without ambiguity.

The position of the rotor as derived from the code sequence may be compared with the position determined by counting, from a known initial position, the rising edges of the sensor signals as in the basic system. The code repeats itself and is fed serially into a shift register within the controller. Therefore, the constant monitoring of the code allows the controller to determine the rotor position according to the state of the sequence in the shift register. If a full correct code is received then it may be assumed that this gives the correct position. If this position also matches the counted position, correct operation is confirmed. If it does not match the counted position, it may be assumed that an error has occurred and the counted position may be updated to coincide with the position defined by the code sequence, thus detecting and correcting the error. The drive should then continue to work normally by counting the rising edges. If, however, no correct code is available from the sensor input (e.g. if the code has been corrupted by electrical noise), the drive may continue to operate by counting the rising edges or may be switched off and allowed to coast until a correct code sequence is received.

If the direction of rotation is to be reversed, the sensor output may be inverted to keep the evenly spaced edges as rising edges. The received code will then be the same as in the forward direction, but in a different angular position relative to the stator poles. The starting of the drive (discussed later) and the reading of the code will be the same as for the original direction of rotation, but the conversion from the code input to the three detector equivalent outputs, i.e. the sequencing of the three phases, will be different.

To decode the output of the sensor one looks at the mark/space ratio of the incoming signal at every rising edge and determines if the last pulse was long or short. If the pulse was long then it may be decoded as a one and if it was short to decode it as a zero. The decoded bit may then be input to the shift register of six bits length so keeping a record of the recent history of the sensor output, the state of the sequence being a reflection of the rotor position. A simple way to decide if the pulse is long or short is to count the time for which the signal is high and the time for which it is low and then to compare them. If the time were counted by a fixed rate clock, then the clock rate would have to be high to achieve a good resolution at the top speed. This would require a large number of bits to enable the system to operate at the lower speeds. For this reason a clock rate may be used which is frequency-locked to the (angularly evenly spaced) rising edges of the RPT input.

It was noted above that operation of the single-detector system required knowledge of the initial position of the rotor at starting. A known initial position may be achieved as follows. If any one phase is excited for a time, the rotor will usually be pulled into approximate alignment with the maximum inductance position of that phase. Alternatively, if two phases are simultaneously excited for a time, the rotor may be pulled approximately to the position between the two maximum inductance positions at which the positive and negative torques of the two phases balance each other. It is possible that the initial rotor position will occasionally correspond to an undesired zero-torque position and the rotor will therefore fail to be pulled into the desired alignment. Failure to pull in to the desired initial position will probably result in failure to start correctly. This condition may be detected and the motor stopped and restarted.

If such a false start cannot be tolerated, it may be avoided by following an initialisation sequence, for example by energising first one phase alone and then the two phases together. The desired position may correspond to one of the transition edges of the RPT signal, i.e. at the boundary of a 15 degree region. In practice, the rotor may come to rest at either side of this transition. However, the correct phase switching sequence on starting can be assured by noting whether the signal is high or low, i.e. in which of the 15-degree regions the rotor is positioned.

The system described allows full starting torque in either direction of rotation. The system can be simplified for drives which require only modest starting torque and in which the ratio of friction to inertia is not high. This development will now be described.

Figure 4 illustrates the sensor output and phase energisation for the simplified system. The detector signal transitions may occur in this example at the maximum and minimum inductance of phase A and this signal may therefore be used to control directly the energisation of phase A. The initial rotor position is assumed in Figure 4 to have been established with both phases A and C energised. Phase C may then be switched off causing the motor to accelerate in the forward direction due to the torque produced by phase A. Phase A is switched off at its position of maximum inductance and the motor then coasts with zero developed torque until phase A is again switched on at the next rising edge of the transducer signal. Thus, one phase is switched directly according to the rising and falling edges of the sensor output. Once the rotor is underway it runs up as a single-phase machine until the motion of the rotor is sufficient for the motor control to establish itself.

There will be a lower limit on the rate of the rotation of the rotor below which the polyphase control is not possible. Once this speed is exceeded and a correct code sequence or sequences have been received, the position of the rotor relative to the stator can be determined and polyphase control effected. It is clear that, to ensure starting, the energy imparted to the rotor over the relatively short initial energisation of phase A must be sufficient to carry the rotor against the friction and load torque through more than 45 degrees to the next energisation of phase A. Phase A may then be energised for a full 45 degrees. The motor accelerates in this manner, with only phase A being energised, until a sufficient speed is achieved for reliable timing of energisation of phases B and C from the transducer signal.

It will be clear that the motor may be started in the reverse direction of rotation if the initial rotor position is established with phases A and B energised and if the transducer signal is inverted. The coded rotating member has been positioned so that in the example phase A is initially excited. Repositioning of the member would allow either phase B or C to be the initially excited phase.

The severity of the restriction on starting torque may be reduced by modifying the system as follows. The transducer coded disc is modified to give a signal as illustrated in Figure 5, i.e. with a mark:space ratio of 1:2, with the rising edges corresponding to the maximum inductance of phase A and the falling edge to the maximum of phase B. The rotor may be initially positioned with phases A and C energised as before. Starting is initiated by turning off phase C, leaving A energised. At the sensor edge, phase A is turned off. Up to this point the arrangement is unchanged, with the same amount of energy being imparted to the rotor as in the unmodified system. However, as phase A is turned off, phase B is turned on. The rotor continues to rotate to the aligned position of phase B, when B is turned off, and it will then coast to the next RPT signal edge.

This arrangement gives a higher initial pulse of energy to the rotor before coasting, and after the aligned position of B is reached, the drive will run up using phase B only. Note that only 30 degrees of the B phase region is used for such operation.

The specific example described above is a 6/4-pole, 3-phase motor drive. In this case the code sequence repeats itself four times in the rotor cycle to coincide with the number of rotor poles. For a different number of rotor poles, a corresponding number of repetitions of the code sequence can be used so that the position of the rotor from a known start-up position can be determined. Of course, a single sequence for the rotor cycle can be used. However, the delay before a complete cycle has been read may be too long. It will be clear that the invention may be used for motors with other pole combinations and with phase numbers other than three. It will also be clear that the invention may be used for generators as well as motors. The RPT detector may use optical, Hall-effect, inductive or other means.

This method according to the invention can be used to start a single phase machine bearing the rotor position encoder. The location of the rotor can be defined by using any of a number of known methods such that the rotor position will be the same each time. For example see EP-A-0601818 in which a host pole carries a permanent magnet that holds the rotor in a start position while it is at rest. The rotor position encoder is then used to monitor the position of the rotor within the cycle on start-up. The single phase is energised and the rising (i.e. leading) edges evenly spaced on the encoder are counted until the maximum inductance position is reached.

At this point the phase is de-energised. The motor then freewheels from this known position until the correct phase energisation position is indicated by counting the rising edges again. Depending on the length of the code, the code sequence will be recognised eventually. The position calculated by counting the rising edges from the position of maximum inductance can then be confirmed from the recognised sequence or corrected.

Similarly, the method can be used to start a two-phase machine. Both motor phases are energised to bring the rotor into a known position. One phase is then de-energised to cause the rotor to move in a defined direction. The sensor/controller arrangement then counts the rising edges until it is calculated that the rotor has reached a position at which the remaining energised phase can be turned off and the de-energised phase turned on again. When the encoder code sequence is eventually recognised, the rotor position can be confirmed or corrected as counted from the known start-up position.

As an alternative, the two-phase start sequence may comprise energising one motor phase to rotate the rotor to a known position (eg. of maximum inductance), de-energising the energised one phase and then energising the other phase. The rising edges from the encoder are counted from energisation of the other phase to determine when to switch it off and turn on the one phase again. Again, the code sequence will eventually be decoded so that the counted rotor position can be confirmed or corrected.

A further method of starting a polyphase electric machine comprises first starting as a stepper motor without rotor position feedback instead of establishing first a known initial rotor position, i.e. using open-loop stepping to start the motor and cause it to run at low speed. This may be accomplished by feeding timing pulses in sequence to the phases from a fixed or variable-frequency oscillator. Thereafter control of switching can be transferred from open-loop stepping to sensor-based control. The sensor output is then used to check the angular position of the rotor through the code sequence.

Claims

1. A method of starting an electric machine (14) comprising a rotor, defining rotor poles, a stator defining stator poles (A/A';B/B';C/C'), an encoder (18) arranged to rotate with the rotor and to provide a rotor position code, a sensor (16) arranged to be influenced by the encoder according to the position code and to produce an output thereof, and a controller (24) for receiving the output from the sensor, the encoder comprising a set of features (20) mountable to rotate with the rotor for influencing the output of the sensor, the method comprising energising at least a selection of the stator poles to orientate the rotor with respect to the stator into a predetermined position; characterised in that the features of the encoder have sensor output influencing first parts which are in evenly spaced angular positions, and sensor output influencing second parts which are in unevenly spaced angular positions, the said angular positions of the second parts relative to the first parts being decodable as a sequence

such that the position of the rotor relative to the stator is determinable from the sequence, and in that the method further comprises; initiating a count of the first parts of the encoder from the known position; accelerating the rotor according to the continued energisation of the stator poles based on the position count derived from the first parts of the encoder and thereafter checking the rotor position from the count with the decoded sequence.

2. A method as claimed in claim 1 in which the machine is a polyphase electric machine, the method comprising energising a set of the stator poles associated with one phase so that the rotor assumes the predetermined position substantially of maximum inductance (A_{MAX}; B_{MAX}) for the said set of stator poles in relation to the rotor; de-energising the stator poles of the one phase; energising an adjacent set of poles associated with another of the phases; monitoring the passage of the rotor past the stator poles according to the position code from the encoder; and energising successive sets of stator poles associated with successive phases in accordance with the monitored position of the rotor in relation to the stator.

3. A method as claimed in claim 1 in which the machine is a polyphase electric machine and in which the evenly spaced first parts are periodic with the phase inductance cycle of the machine, the method further comprising: energising the sets of poles of two adjacent phases of the machine so that the rotor assumes the position intermediate the maximum inductance positions associated with the two phases; de-energising one of the sets of poles such that the rotor rotates towards the maximum inductance position of the other energised set of poles; monitoring the passage of the rotor past the stator poles according to the position code from the encoder; de-energising the other of the sets of poles at a moment that assists in allowing the rotor to freewheel past the said maximum inductance position; and continuing rotation of the rotor by energising and de-energising the said other phase according to the monitored position of the rotor.

4. A method as claimed in claim 3, further including, after de-energising the other set of stator poles, energising a third set of stator poles to maintain rotation of the rotor and continuing rotation of the rotor by energising and de-energising the stator poles according to the monitored position of the rotor.

Patentansprüche

1. Verfahren zum Starten einer elektrischen Maschine (14), bestehend aus einem Rotor mit Rotorpolen, einem Stator mit Statorpolen (A/A'; B/B'; C/C'), einem zur Drehung mit dem Rotor und zur Bereitstellung eines Rotorstellungscodes angeordneten Codierer (18), einem zur Beeinflussung durch den Codierer gemäß dem Stellungscode und zur Erzeugung eines Ausgangssignals davon angeordneten Sensor (16) und einem Steuergerät (24) zum Empfang des Sensorausgangssignals, wobei der Codierer aus einem zur Drehung mit dem Rotor montierbaren Satz von Markierungen (20) zur Beeinflussung des Sensorausgangs besteht und das Verfahren die Erregung mindestens eines ausgewählten Teils der Statorpole umfaßt, um den Rotor in Bezug auf den Stator in eine vorbestimmte Stellung zu bringen; dadurch gekennzeichnet, daß die Markierungen des Codierers erste Teile zur Beeinflussung des Sensorausgangs in gleichförmig verteilten Winkelstellungen und zweite Teile zur Beeinflussung des Sensorausgangs in ungleichförmig verteilten Winkelstellungen aufweisen, wobei besagte Winkelstellungen der zweiten Teile bezüglich der ersten Teilen als eine Folge derart decodierbar sind, daß die Relativstellung des Rotors gegenüber dem Stator aus dieser Folge bestimmbar ist; und dadurch gekennzeichnet, daß das Verfahren weiterhin eine Zählung der ersten Teile des Codierers ausgehend von der bekannten Stellung, die Beschleunigung des Rotors durch die fortgesetzte Erregung der Statorpole gemäß der aus den ersten Teilen des Codierers abgeleiteten Stellungszählung und die nachfolgende Überprüfung der durch Zählung bestimmten Rotorstellung anhand der dekodierten Folge umfaßt.

2. Verfahren nach Anspruch 1, wobei die Maschine eine mehrphasige elektrische Maschine ist und das Verfahren umfaßt: Erregung des einer Phase zugeordneten Statorpolsatzes, so daß der Rotor die vorbestimmte Stellung im wesentlichen maximaler Induktivität (A_{MAX}; B_{MAX}) für besagten Statorpolsatz in Bezug auf den Rotor annimmt; Entregung der Statorpole der einen Phase; Erregung eines benachbarten Polsatzes einer anderen Phase; Überwachung des Vorbeilaufs des Rotors an den Statorpolen gemäß dem Stellungscode des Codierers; und Erregung aufeinanderfolgender Sätze von Statorpolen, die zu aufeinanderfolgenden Phasen gehören in Übereinstimmung mit der überwachten Stellung des Rotors gegenüber dem Stator.

3. Verfahren nach Anspruch 1, wobei die Maschine eine mehrphasige elektrische Maschine ist, in der die in gleichmäßigem Abstand angeordneten ersten Teile periodisch mit dem Phaseninduktivitätszyklus der Maschine sind und das Verfahren weiterhin umfaßt: Erregung der Polsätze zweier benachbarter Phasen der Maschine, so daß der Rotor die Mittelstellung zwischen den Stellungen maximaler Induk-

tivität der zwei Phasen annimmt; Entregung eines der Polsätze, so daß sich der Rotor in Richtung auf die Stellung maximaler Induktivität des anderen erregten Polsatzes bewegt; Überwachung des Vorbeilaufs des Rotors an den Statorpolen in Übereinstimmung mit dem Stellungscode des Codierers ; Entregung des anderen Polsatzes zu einem Zeitpunkt, der den Freilauf des Rotors durch die genannte Stellung maximaler Induktivität unterstützt; und Fortsetzung der Drehbewegung des Rotors durch Erregung und Entregung der besagten anderen Phase in Übereinstimmung mit der überwachten Rotorstellung.

4. Verfahren nach Anspruch 3, das weiterhin nach der Entregung des anderen Statorpolsatzes die Erregung eines dritten Statorpolsatzes zur Aufrechterhaltung der Drehbewegung des Rotors und zur Fortsetzung der Drehbewegung des Rotors durch Erregung und Entregung der Statorpole gemäß der überwachten Rotorstellung umfaßt.

Revendications

1. Méthode de démarrage d'une machine électrique (14) comportant un rotor définissant des pôles de rotor, un stator définissant des pôles de stator (A/A'; B/B'; C/C'), un codeur (18) monté de manière à tourner avec le rotor et produire un code de position du rotor, un capteur (16) monté de manière à être influencé par le codeur selon le code de position et à produire un signal de sortie, et un système de commande (24) recevant le signal de sortie du capteur, le codeur comprenant des protubérances (20) qui tournent avec le rotor et qui influent sur le signal de sortie du capteur, la méthode consistant à alimenter au moins une sélection des pôles du stator pour orienter le rotor relativement au stator et le placer dans une position prédéterminée; caractérisée par le fait que les protubérances du codeur comprennent des premières parties influant sur le signal de sortie du capteur qui occupent des positions angulaires à espacement uniforme, et des deuxièmes parties influant sur le signal de sortie du capteur qui occupent des positions angulaires à espacement inégal, lesdites positions angulaires des deuxièmes parties relativement aux premières parties étant décodables sous forme de séquence permettant de déterminer la position du rotor par rapport au stator, et caractérisée également par le fait que la méthode consiste aussi à entamer un comptage des premières parties du codeur à partir de la position connue; à faire accélérer le rotor selon l'alimentation poursuivie des pôles du stator d'après le comptage de position obtenu des premières parties du codeur, et par la suite à vérifier la position du rotor à partir du comptage avec la séquence décodée.

2. Méthode, selon la revendication 1, dans laquelle la machine est une machine électrique polyphasée, la méthode consistant à alimenter un groupe de pôles du stator correspondant à l'une des phases de sorte que le rotor se place dans la position prédéterminée ayant essentiellement l'inductance maximum (A_{max}; B_{max}) pour ledit groupe de pôles du stator relativement au rotor; à mettre hors tension les pôles du stator de l'une des phases; à alimenter un groupe adjacent de pôles correspondant à l'une des autres phases; à surveiller le passage du rotor devant les pôles du stator selon le code de position venant du codeur; et à alimenter des groupes successifs de pôles du stator correspondant à des phases successives conformément à la position surveillée du rotor par rapport au stator.

3. Méthode, selon la revendication 1, dans laquelle la machine est une machine électrique polyphasée, et dans laquelle les premières parties à espacement uniforme sont périodiques avec le cycle d'inductance des phases de la machine, la méthode consistant aussi: à alimenter les groupes de pôles de deux phases adjacentes de la machine de sorte que le rotor se place dans une position intermédiaire entre les positions d'inductance maximum correspondant aux deux phases; à mettre hors tension l'un des groupes de pôles de sorte que le rotor tourne vers la position d'inductance maximum de l'autre groupe de pôles alimenté; à surveiller le passage du rotor devant les pôles du stator selon le code de position venant du codeur; à mettre hors tension l'autre groupe de pôles à un moment qui contribue à faciliter la rotation du rotor en roue libre au-delà de ladite position d'inductance maximum; à continuer de faire tourner le rotor en alimentant et en mettant hors tension cette autre phase en fonction de la position surveillée du rotor.

4. Méthode, selon la revendication 3, consistant aussi, après la mise hors tension de l'autre groupe de pôles du stator, à alimenter un troisième groupe de pôles du stator pour maintenir la rotation du rotor et continuer à le faire tourner en alimentant et en mettant hors tension le groupe de pôles du stator en fonction de la position surveillée du rotor.

FIG.1.

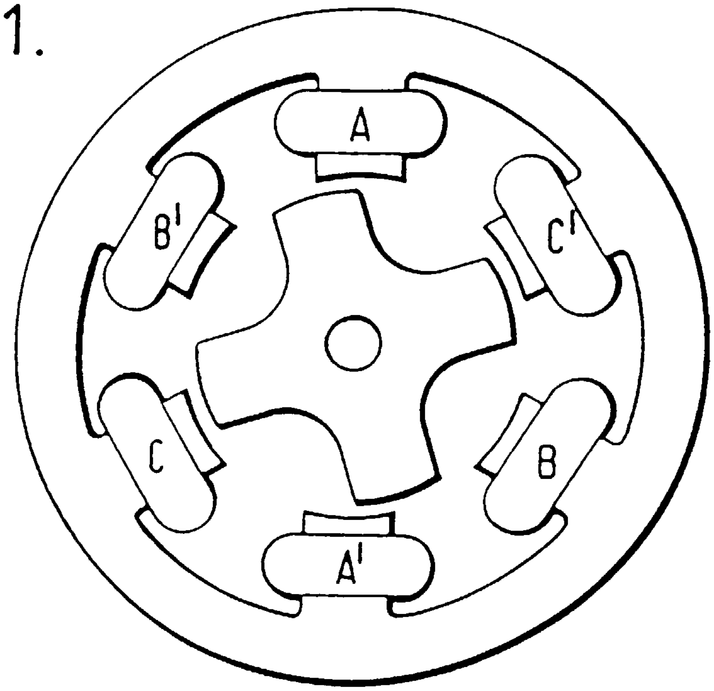
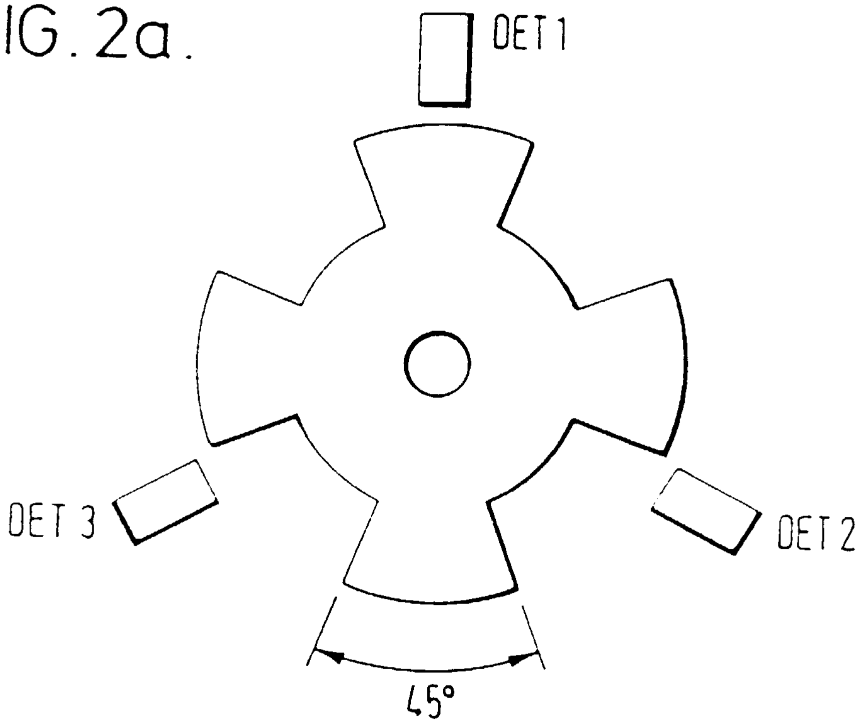


FIG.2a.



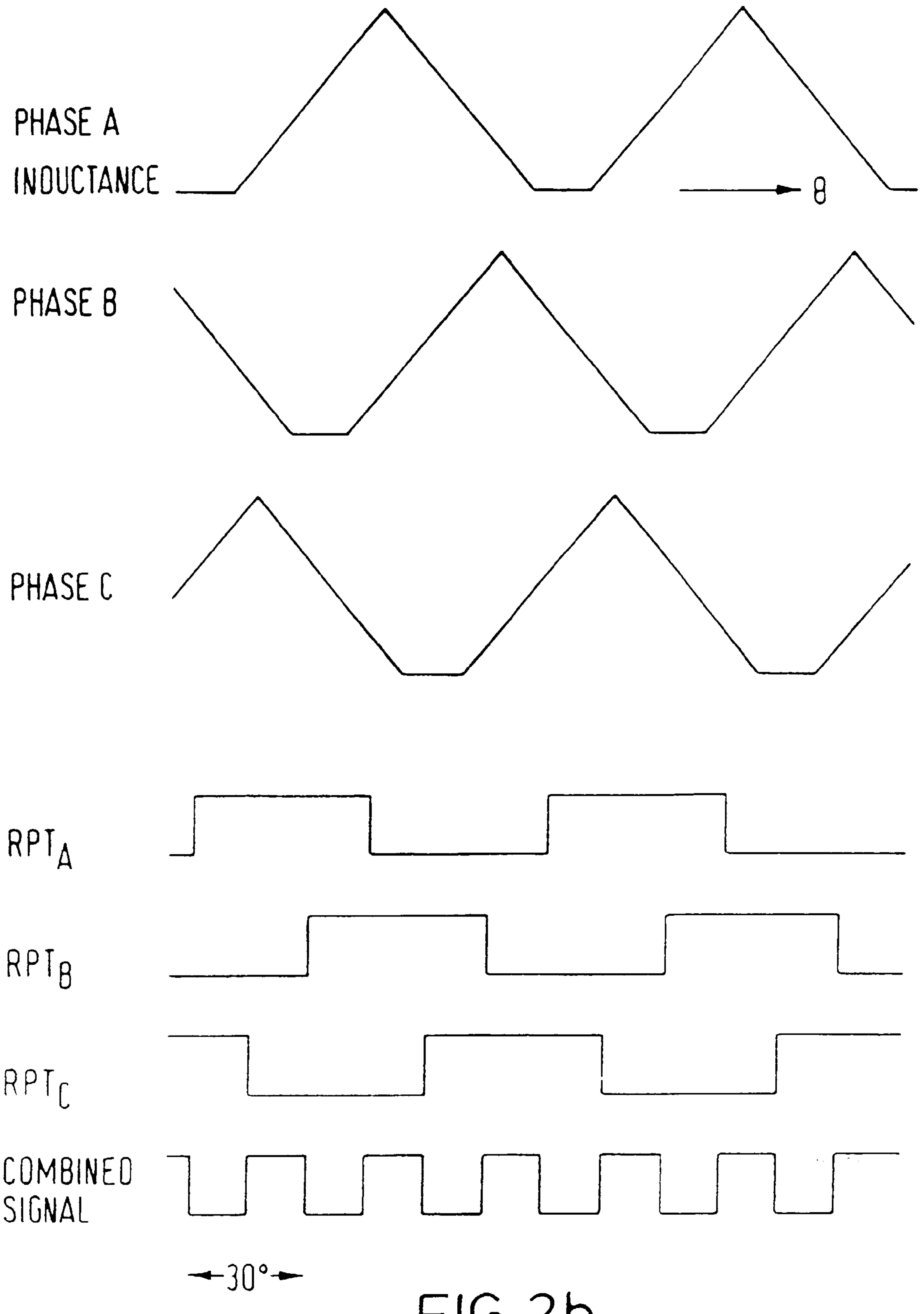

PHASE A
INDUCTANCE
θ
PHASE B
PHASE C
RPT_A
RPT_B
RPT_C
COMBINED
SIGNAL
30°

FIG. 2b.

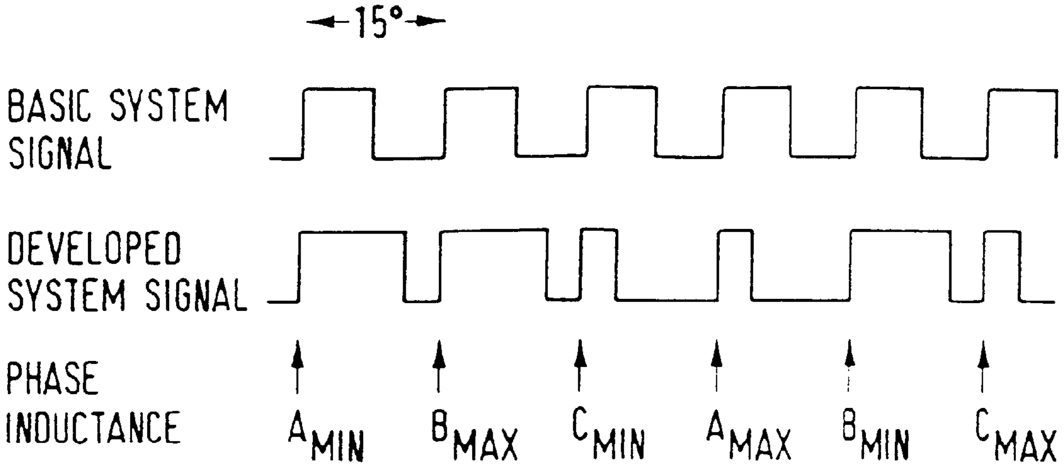

15°
BASIC SYSTEM SIGNAL
DEVELOPED SYSTEM SIGNAL
PHASE INDUCTANCE
A_{MIN}
B_{MAX}
C_{MIN}
A_{MAX}
B_{MIN}
C_{MAX}

FIG.3.

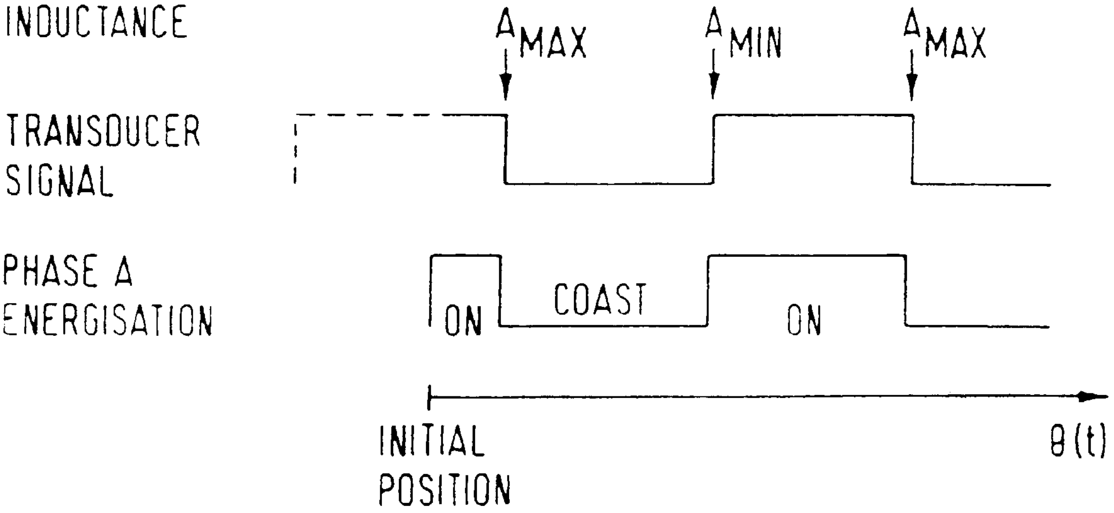

INDUCTANCE
A_{MAX}
A_{MIN}
A_{MAX}
TRANSDUCER SIGNAL
PHASE A ENERGISATION
ON
COAST
ON
INITIAL POSITION
θ(t)

FIG 4

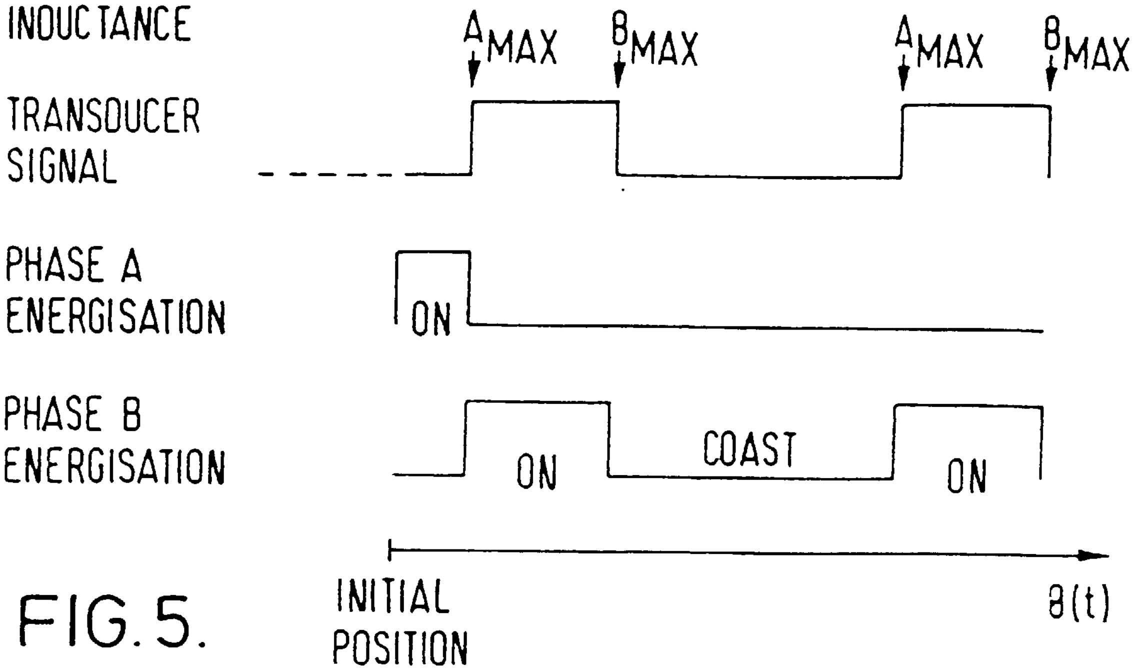

INDUCTANCE
TRANSDUCER SIGNAL
A MAX
B MAX
A MAX
B MAX
PHASE A ENERGISATION
ON
PHASE B ENERGISATION
ON
COAST
ON
INITIAL POSITION
θ(t)

FIG. 5.

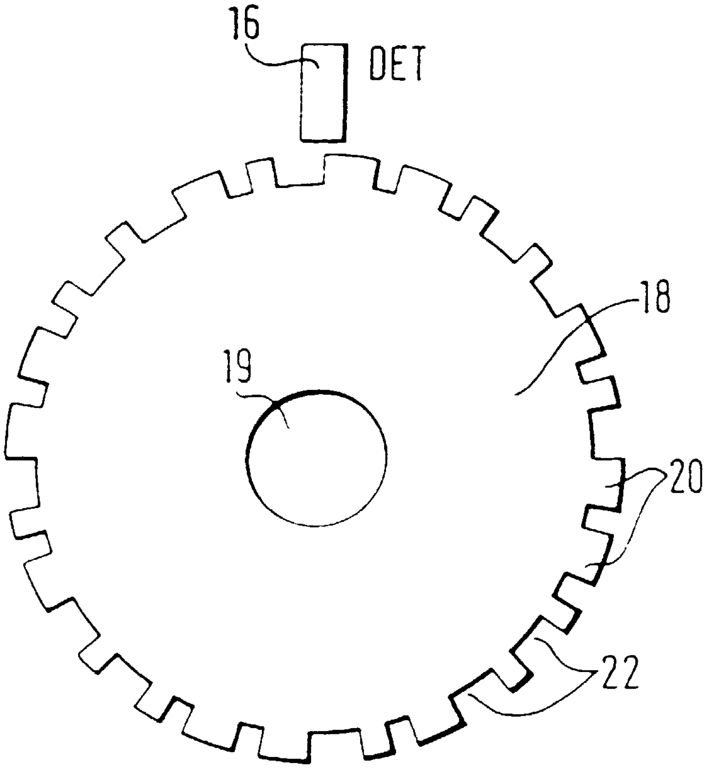
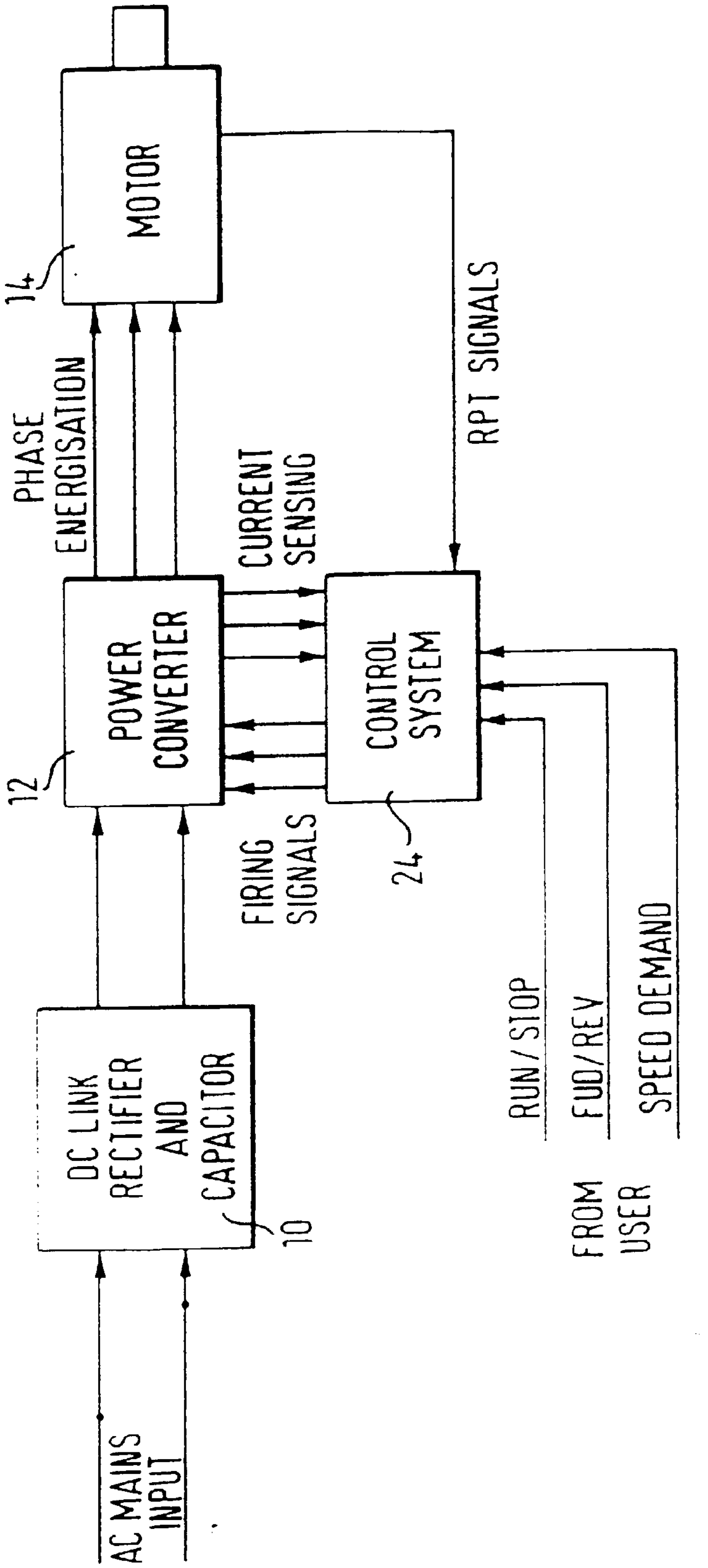

16
DET
18
19
20
22

FIG.7.

FIG.6.


AC MAINS INPUT
DC LINK RECTIFIER AND CAPACITOR
10
POWER CONVERTER
12
MOTOR
14
PHASE ENERGISATION
CURRENT SENSING
FIRING SIGNALS
CONTROL SYSTEM
24
RPT SIGNALS
RUN/STOP
FWD/REV
SPEED DEMAND
FROM USER